

**Before The North Dakota Department of Health**

**Hearing Regarding Proposed Determination of the  
Adequacy of the North Dakota State Implementation  
Plan to Prevent Significant Deterioration**

**Appendix of Exhibits  
to Great River Energy's  
Post-Hearing Comments**

# Assessment of Trends in Measured Ambient Sulfur Dioxide Concentrations Within Theodore Roosevelt National Park

*Prepared for:*  
The Environmental Law Group, Ltd.  
10 Second Street Northeast  
Minneapolis, Minnesota 55413

*Prepared by:*  
Earth Tech, Inc.  
3033 Campus Drive North  
Suite 175  
Minneapolis, Minnesota 55441

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## 1.0 INTRODUCTION

The purpose of this report is to evaluate the trends of measured sulfur dioxide (SO<sub>2</sub>) concentrations in North Dakota's Theodore Roosevelt National Park (TRNP). The TRNP is divided into three geographic units: the North Unit, the South Unit, and the Elkhorn Ranch Unit. Figure 1 shows where the TRNP's units are located in North Dakota.

North Dakota is classified as attainment or unclassified for all criteria pollutants. The TRNP is classified as a Class I area with regard to available ambient increments. Ambient increments are promulgated in 40 CFR Part 52.21(c). The ambient increment allows specified increases in ambient air concentrations above a baseline level. In the case of the TRNP, baseline ambient air concentrations are defined as the air quality existing in 1978. Table 1 provides the allowable ambient increments for SO<sub>2</sub>.

TABLE 1

### CLASS I AMBIENT INCREMENTS FOR SO<sub>2</sub>

Annual Average	2 µg/m <sup>3</sup>
24-Hour Maximum	5 µg/m <sup>3</sup>
3-Hour Maximum	25 µg/m <sup>3</sup>

The 24-hour and 3-hour maxima may be exceeded once per year at any one location.

The North Dakota Department of Health's (NDDH) Division of Air Quality (DAQ) has operated pulsed fluorescent ambient SO<sub>2</sub> monitors in the North and South Units of the TRNP since 1980. Earth Tech obtained the available hourly average SO<sub>2</sub> concentrations directly from the DAQ. It is the same data submitted by the DAQ to the US Environmental Protection Agency's (USEPA) Aerometric Information Retrieval System (AIRS).

## **2.0 RELIABILITY OF AMBIENT SO<sub>2</sub> MEASUREMENT**

### **2.1 AMBIENT SO<sub>2</sub> MEASUREMENT METHODOLOGY**

The North Dakota Department of Health (NDDH) has monitored ambient SO<sub>2</sub> concentrations using the continuous instrumental pulsed fluorescent method at specific locations in the Theodore Roosevelt National Park (TRNP) since 1980. The pulsed fluorescent method involves drawing ambient air through a sample chamber where it is irradiated with pulses of ultra-violet light. This exposure causes any SO<sub>2</sub> in the sample to release a characteristic light or fluorescence. The amount of fluorescence measured is proportional to the SO<sub>2</sub> concentration.

The pulsed fluorescent method is a recognized continuous monitoring method for ambient SO<sub>2</sub> in accordance with the regulatory requirements for designation of reference or equivalent monitoring methods under 40 CFR 53.

### **2.2 EPA APPROVAL CRITERIA**

The Federal EPA has established detailed regulations applicable to ambient air quality surveillance under 40 CFR 58. These types of requirements, which include detailed quality assurance/quality control (QA/QC) procedures and documentation, have applied over the history of NDDH's pulsed fluorescent ambient SO<sub>2</sub> monitoring in TRNP since 1980. All of the NDDH's pulsed fluorescent ambient SO<sub>2</sub> included in this evaluation have been obtained directly from the NDDH's Division of Air Quality, Air Quality Monitoring Branch. The ambient SO<sub>2</sub> data included in this evaluation are the same data submitted by NDDH to the US Environmental Protection Agency's (USEPA) Aerometric Information Retrieval System (AIRS) and satisfy USEPA QA/QC requirements.

### 3.0 DATA PROCESSING

The NDDH's Division of Air Quality (DAQ) has periodically operated pulsed fluorescent ambient SO<sub>2</sub> monitors in the North and South Units of the TRNP since 1980. Figures 2 and 3 provide maps of the locations of the TRNP monitoring sites based on the geographic coordinates listed in AIRS. More detailed location maps of the monitoring sites are provided in Appendix A. Table 2 provides the AIRS monitor codes for each location. Appendix B contains a compact disc containing the data provided by the NDDH.

**TABLE 2**

**AIRS IDENTIFICATION CODES FOR TRNP MONITOR LOCATIONS**

<b>Monitor Location</b>	<b>State Code</b>	<b>County Code</b>	<b>Site Code</b>	<b>POC Code</b>
North Unit	38	053	0002	1
South Unit A (Peaceful Valley)	38	007	0001	1
South Unit B (Painted Canyon)	38	007	0002	1

The raw 1-hour average data were processed in accordance with the procedures specified in 40 CFR Part 50.4 and 50.5 for 24-hour and 3-hour averages, respectively. The 24-hour averages were calculated from successive nonoverlapping 24-hour blocks starting at midnight each calendar day. The second-highest 24-hour averages were based upon hourly data that were at least 75 percent complete in each calendar quarter. A 24-hour block average was considered valid if at least 75 percent of the hourly averages for the 24-hour period were available. In the event that only 18, 19, 20, 21, 22, or 23 hourly averages were available, the 24-hour block average was computed as the sum of the available hourly averages using 18, 19, etc. as the divisor. If fewer than 18 hourly averages were available, the 24-hour average was calculated with zeros substituted for the missing values. In these cases, the 24-hour block average was computed as the sum of the available hourly averages divided by 24.

Similarly, the 3-hour averages were calculated from successive nonoverlapping 3-hour blocks starting at midnight each calendar day. The second-highest 3-hour averages were based upon hourly data that were at least 75 percent complete in each calendar quarter. A 3-hour block average was considered valid only if all three hourly averages for the 3-hour period were available. If only one or two hourly averages were available, the 3-hour average was calculated with zeros substituted for the missing values. In these cases, the 3-hour block average was computed as the sum of the available hourly averages divided by 3.

The raw 1-hour average data included missing observations which were treated in accordance with the above discussion. Additionally, numerous observations were reported as zero. Earth Tech conservatively treated these observations as equal to the minimum detection limit (MDL) of the instruments used to measure SO<sub>2</sub> concentrations. Three different method codes were assigned to the data: 020, 009, and 060. All three methods are pulsed fluorescence methods, although each code represents a specific analyzer. The MDL for the methods employed are listed in AIRS as 2 ppb. However, NDDH treats the MDL of the Method 060 analyzer as equal to 1 ppb. Therefore, Earth Tech treated the MDL as 1 ppb (2.62 µg/m<sup>3</sup> @ 25°C and 1 atmosphere) for Method 060 values and as 2 ppb (5.24 µg/m<sup>3</sup> @ 25°C and 1 atmosphere) for Methods 020 and 009 and used these values to replace the reported zero values.

Figure 4 provides a chart of the quarterly data completeness for each monitoring location. The values are also tabulated in Table 3. For those cases where data completeness was less than 75 percent for a calendar quarter, data for the quarter were considered incomplete and 3-hour and 24-hour average concentrations were not calculated.

**TABLE 3**  
**QUARTERLY DATA COMPLETENESS – 1-HOUR AVERAGE SO<sub>2</sub> DATA**

Year	Quarter	North Unit		South Unit A		South Unit B	
		Completeness	Complete?	Completeness	Complete?	Completeness	Complete?
1980	1	50.8%	No	69.5%	No	No Data	
	2	99.4%	Yes	78.8%	Yes	No Data	
	3	99.5%	Yes	99.2%	Yes	No Data	
	4	99.5%	Yes	99.3%	Yes	No Data	
1981	1	99.4%	Yes	96.6%	Yes	No Data	
	2	98.4%	Yes	91.7%	Yes	No Data	
	3	99.1%	Yes	93.3%	Yes	No Data	
	4	99.1%	Yes	93.8%	Yes	No Data	
1982	1	98.3%	Yes	95.1%	Yes	No Data	
	2	98.5%	Yes	78.8%	Yes	No Data	
	3	97.7%	Yes	95.2%	Yes	No Data	
	4	98.7%	Yes	92.7%	Yes	No Data	
1983	1	99.4%	Yes	98.6%	Yes	No Data	
	2	99.2%	Yes	98.1%	Yes	No Data	
	3	67.8%	No	97.1%	Yes	No Data	
	4	98.9%	Yes	99.3%	Yes	No Data	
1984	1	85.3%	Yes	98.5%	Yes	No Data	
	2	99.2%	Yes	76.4%	Yes	No Data	
	3	93.7%	Yes	90.2%	Yes	No Data	
	4	98.1%	Yes	93.4%	Yes	No Data	
1985	1	86.4%	Yes	99.2%	Yes	No Data	
	2	95.9%	Yes	99.2%	Yes	No Data	
	3	98.5%	Yes	97.6%	Yes	No Data	
	4	98.7%	Yes	16.7%	No	77.1%	Yes
1986	1	99.3%	Yes	No Data		89.2%	Yes
	2	98.4%	Yes	No Data		95.2%	Yes
	3	98.7%	Yes	No Data		97.6%	Yes
	4	99.3%	Yes	No Data		99.3%	Yes
1987	1	99.2%	Yes	No Data		99.1%	Yes
	2	78.1%	Yes	No Data		99.4%	Yes
	3	84.7%	Yes	No Data		99.4%	Yes
	4	99.1%	Yes	No Data		86.4%	Yes
1988	1	99.5%	Yes	No Data		97.6%	Yes
	2	99.3%	Yes	No Data		99.5%	Yes
	3	99.1%	Yes	No Data		97.6%	Yes
	4	99.4%	Yes	No Data		99.4%	Yes
1989	1	99.4%	Yes	No Data		99.2%	Yes
	2	99.3%	Yes	No Data		99.5%	Yes
	3	99.2%	Yes	No Data		98.8%	Yes
	4	99.4%	Yes	No Data		99.5%	Yes
1990	1	99.4%	Yes	No Data		99.2%	Yes
	2	99.1%	Yes	No Data		99.4%	Yes
	3	99.0%	Yes	No Data		No Data	
	4	99.4%	Yes	No Data		No Data	

TABLE 3  
(CONTINUED)

QUARTERLY DATA COMPLETENESS - 1-HOUR AVERAGE SO<sub>2</sub> DATA

Year	Quarter	North Unit		South Unit A		South Unit B	
		Completeness	Complete?	Completeness	Complete?	Completeness	Complete?
1991	1	99.4%	Yes	No Data		No Data	
	2	97.7%	Yes	No Data		No Data	
	3	99.0%	Yes	No Data		No Data	
	4	99.5%	Yes	No Data		No Data	
1992	1	99.4%	Yes	No Data		No Data	
	2	99.3%	Yes	No Data		No Data	
	3	99.0%	Yes	No Data		No Data	
	4	99.5%	Yes	No Data		No Data	
1993	1	99.4%	Yes	No Data		No Data	
	2	99.2%	Yes	No Data		No Data	
	3	99.4%	Yes	No Data		No Data	
	4	99.5%	Yes	No Data		No Data	
1994	1	99.4%	Yes	No Data		No Data	
	2	99.5%	Yes	No Data		No Data	
	3	99.2%	Yes	No Data		No Data	
	4	99.4%	Yes	No Data		No Data	
1995	1	65.8%	No	No Data		No Data	
	2	99.4%	Yes	No Data		No Data	
	3	53.7%	No	No Data		No Data	
	4	99.4%	Yes	No Data		No Data	
1996	1	99.4%	Yes	No Data		No Data	
	2	99.6%	Yes	No Data		No Data	
	3	91.6%	Yes	No Data		No Data	
	4	99.2%	Yes	No Data		No Data	
1997	1	77.5%	Yes	No Data		No Data	
	2	99.4%	Yes	No Data		No Data	
	3	99.4%	Yes	No Data		No Data	
	4	99.5%	Yes	No Data		No Data	
1998	1	99.4%	Yes	No Data		No Data	
	2	98.4%	Yes	No Data		No Data	
	3	No Data		No Data		66.4%	No
	4	No Data		No Data		99.3%	Yes
1999	1	No Data		No Data		99.2%	Yes
	2	No Data		No Data		73.1%	No
	3	No Data		No Data		99.2%	Yes
	4	No Data		No Data		99.3%	Yes
2000	1	No Data		No Data		86.6%	Yes
	2	No Data		No Data		86.9%	Yes
	3	No Data		No Data		99.4%	Yes
	4	No Data		No Data		99.3%	Yes
2001	1	No Data		No Data		99.4%	Yes
	2	No Data		No Data		99.1%	Yes
	3	65.7%	No	No Data		99.3%	Yes
	4	99.0%	Yes	No Data		99.5%	Yes



#### 4.0 DATA ANALYSIS

Concentrations measured at the North Unit are generally greater than concentrations measured at the South Unit. 24-hour average concentrations are variable, ranging from the MDL of  $2.62 \mu\text{g}/\text{m}^3$  to  $162 \mu\text{g}/\text{m}^3$  at the North Unit and ranging from the MDL of  $2.62 \mu\text{g}/\text{m}^3$  to  $35.6 \mu\text{g}/\text{m}^3$  at the South Unit. The 3-hour average concentrations are also variable, ranging from the MDL of  $2.62 \mu\text{g}/\text{m}^3$  to  $399 \mu\text{g}/\text{m}^3$  at the North Unit and ranging from the MDL of  $2.62 \mu\text{g}/\text{m}^3$  to  $93.5 \mu\text{g}/\text{m}^3$  at the South Unit. Figures 5 and 6 respectively present time series plots of the 24-hour and 3-hour average  $\text{SO}_2$  concentrations measured at the North Unit monitoring site. Figures 7 and 8 respectively present the same concentrations measured at the South Unit monitoring sites.

A considerable number of the observations were less than the MDL at all three monitoring sites. Figure 9 presents the percentage of detectable 1-hour average  $\text{SO}_2$  concentrations measured at the three monitoring sites by calendar quarter. Concentrations greater than the MDL are typically measured 5 to 25 percent of the time at the North Unit, and 3 to 15 percent of the time at the South Unit.

The upper percentiles of the data, as shown in Figures 5 through 9 provide evidence of a downward concentration trend at the North Unit and seasonality with highest concentrations occurring in the winter. Earth Tech calculated selected percentiles of the 24-hour average  $\text{SO}_2$  concentration data by year and by month. The selected percentiles were the 99<sup>th</sup>, 95<sup>th</sup>, 90<sup>th</sup>, 75<sup>th</sup>, and 50<sup>th</sup> (median). These percentiles were then plotted for both the North and South Units to further evaluate the trend in seasonality.

The upper percentiles by year and by month for the North Unit monitoring site are presented in Figures 10 and 11, respectively. Figure 10 demonstrates that concentrations have decreased over the period of record. Even if the years of 1982 and 1983 are ignored, the trend is a decreasing trend demonstrating improved air quality. Figure 11 demonstrates the seasonal nature of measured  $\text{SO}_2$  concentrations. The highest concentrations are observed during the winter months while the lowest concentrations are observed during the summer months.

Likewise, the upper percentiles by year and by month for the South Unit monitoring site are presented in Figures 12 and 13, respectively. The 50<sup>th</sup> percentile is not presented in either chart because it was equal to the MDL for all years and all months. Figure 12 shows that concentrations have remained constant over the period of record, demonstrating that air quality has not degraded. Figure 13 demonstrates the seasonal nature of measured  $\text{SO}_2$  concentrations. The highest concentrations are observed during the winter months while the lowest concentrations are observed during the summer months.

## **5.0 COMPARISON TO AMBIENT INCREMENTS**

As noted in Table 2, the ambient increments can be exceeded once each year. Therefore, the appropriate concentrations to compare to the ambient increments are the second highest concentration measured each year at each site. Figures 14 and 15 provide plots of the 24-hour average and 3-hour average results, respectively. The values are also tabulated in Tables 4 and 5.

A least squares regression was performed on the log-transformed concentrations of each of the data sets presented in Figures 14 and 15. The data for the two south unit monitors were combined using Monitor A (Peaceful Valley) data from 1980 through the third quarter of 1985 and Monitor B (Painted Canyon) data from the fourth quarter of 1985 to the present. The results are displayed as trend lines. The trend lines for the North Unit data decrease by about a factor of 5 between 1980 and 2000. Therefore, one can reasonably conclude that current air quality in the North Unit is better than the air quality of 1980. The trend lines for the South Unit data are essentially constant across the period of record. Therefore, one can reasonably conclude that air quality has not degraded at the South Unit such that the ambient increments would be exceeded.

The data can also be used to evaluate the magnitude of PSD baseline concentrations needed for current air quality in TRNP to exceed allowable ambient increments. For the purposes of this report, Earth Tech defined current air quality as the most recent complete year of data collected at a monitoring site, which are 1997 and 2001 for the North Unit and South Unit, respectively.

The second highest 24-hour and 3-hour average SO<sub>2</sub> concentrations at the North Unit in 1997 are 10.0 µg/m<sup>3</sup> and 26.2 µg/m<sup>3</sup>, respectively. For these concentrations to be in excess of the allowable ambient increment, baseline 24-hour and 3-hour average SO<sub>2</sub> concentrations at the North Unit would need to be 5.0 µg/m<sup>3</sup> and 1.2 µg/m<sup>3</sup>, respectively. These projected North Unit baseline concentrations are depicted graphically in Figures 16 and 17. Both of these baseline concentrations are less than the MDL of the pulsed fluorescence analyzers available at the time. Given the history of measurable concentrations at the North Unit site, the probability that North Unit baseline concentrations were at undetectable levels is remote.

The second highest 24-hour and 3-hour average SO<sub>2</sub> concentrations at the South Unit in 2001 are 8.80 µg/m<sup>3</sup> and 30.6 µg/m<sup>3</sup>, respectively. For these concentrations to be in excess of the allowable ambient increment, baseline 24-hour and 3-hour average SO<sub>2</sub> concentrations at the South Unit would need to be 3.8 µg/m<sup>3</sup> and 5.6 µg/m<sup>3</sup>, respectively. These projected South Unit baseline concentrations are depicted graphically in Figures 18 and 19 for the 24-hour and 3-hour averaging periods. These baseline concentrations are less than or effectively equal to the MDL of the pulsed fluorescence analyzers available at the time. Given the history of measurable concentrations at the South Unit site, the probability that South Unit baseline concentrations were at undetectable levels is remote.

**TABLE 4**  
**24-HOUR AVERAGE SO<sub>2</sub> DATA BY YEAR**

Year	North Unit				South Unit			
	Max.	2 <sup>nd</sup>	Obs.	Note	Max.	2 <sup>nd</sup>	Obs.	Note
1980	32.2	21.2	87.3%	1 <sup>st</sup> qtr incomplete	10.6	8.85	86.8%	1 <sup>st</sup> qtr incomplete
1981	38.3	31.9	99.0%		13.2	9.23	93.8%	
1982	162	98.1	98.3%		15.3	12.2	90.4%	
1983	40.7	39.3	91.2%	3 <sup>rd</sup> qtr incomplete	13.7	10.1	98.3%	
1984	41.5	27.4	94.1%		10.0	9.83	89.6%	
1985	36.4	30.6	94.9%		8.09	7.65	78.0%	Site A (1 <sup>st</sup> – 3 <sup>rd</sup> qtr)
					13.8	11.7	19.4%	Site B (4 <sup>th</sup> qtr)
1986	29.6	21.6	98.9%		13.7	11.7	95.4%	
1987	12.0	11.8	90.3%		11.1	9.17	96.1%	
1988	21.4	21.3	99.3%		14.1	13.0	98.5%	
1989	31.5	17.5	99.3%		35.6	18.9	99.2%	
1990	13.9	11.1	99.2%		14.3	10.5	49.2%	3 <sup>rd</sup> -4 <sup>th</sup> qtrs incomplete
1991	18.2	12.9	98.9%					no data
1992	12.1	11.6	99.3%					no data
1993	19.3	14.2	99.4%					no data
1994	20.4	20.4	99.4%					no data
1995	14.9	12.6	79.6%	1 <sup>st</sup> , 3 <sup>rd</sup> qtrs incomplete				no data
1996	27.6	21.6	97.4%					no data
1997	10.5	10.0	94.0%					no data
1998	14.4	12.9	49.0%	3 <sup>rd</sup> -4 <sup>th</sup> qtrs incomplete	9.76	9.05	41.8%	1 <sup>st</sup> -3 <sup>rd</sup> qtrs incomplete
1999				no data	10.2	9.92	92.7%	2 <sup>nd</sup> qtr incomplete
2000				no data	9.72	9.39	93.1%	
2001	6.2	5.0	41.5%	1 <sup>st</sup> -3 <sup>rd</sup> qtrs incomplete	10.4	8.80	99.3%	

**TABLE 5**  
**3-HOUR AVERAGE SO<sub>2</sub> DATA BY YEAR**

Year	North Unit				South Unit			
	Max.	2 <sup>nd</sup>	Obs.	Note	Max.	2 <sup>nd</sup>	Obs.	Note
1980	89.1	86.5	87.3%	1 <sup>st</sup> qtr incomplete	30.6	23.6	86.8%	1 <sup>st</sup> qtr incomplete
1981	151	106	99.0%		50.6	23.6	93.8%	
1982	399	364	98.3%		32.3	30.6	90.4%	
1983	188	135	91.2%	3 <sup>rd</sup> qtr incomplete	32.3	29.7	98.3%	
1984	84.7	77.7	94.1%		27.1	24.5	89.6%	
1985	85.6	82.1	94.9%		14.9	14.8	78.0%	Site A (1 <sup>st</sup> – 3 <sup>rd</sup> qtr)
					23.6	22.7	19.4%	Site B (4 <sup>th</sup> qtr)
1986	119	74.2	98.9%		30.5	28.0	95.4%	
1987	41.1	38.4	90.3%		32.3	24.4	96.1%	
1988	65.5	47.2	99.3%		32.3	31.4	98.5%	
1989	69.0	63.8	99.3%		93.5	93.4	99.2%	
1990	33.2	33.2	99.2%		33.2	22.7	49.2%	3 <sup>rd</sup> -4 <sup>th</sup> qtrs incomplete
1991	69.0	28.8	98.9%					no data
1992	34.9	28.8	99.3%					no data
1993	49.8	48.9	99.4%					no data
1994	62.9	59.4	99.4%					no data
1995	38.4	35.8	79.6%	1 <sup>st</sup> , 3 <sup>rd</sup> qtrs incomplete				no data
1996	88.2	48.9	97.4%					no data
1997	27.1	26.2	94.0%					no data
1998	39.3	30.5	49.0%	3 <sup>rd</sup> -4 <sup>th</sup> qtrs incomplete	27.1	26.2	41.8%	1 <sup>st</sup> -3 <sup>rd</sup> qtrs incomplete
1999				no data	24.5	24.4	92.7%	2 <sup>nd</sup> qtr incomplete
2000				no data	24.5	22.7	93.1%	
2001	16.6	14.8	41.5%	1 <sup>st</sup> -3 <sup>rd</sup> qtrs incomplete	39.3	30.6	99.3%	

## **6.0 CONCLUSION**

The results of the TRNP ambient SO<sub>2</sub> evaluation clearly conclude that air quality has not degraded at either the North Unit and South Unit monitoring sites. Further, data collected at the North Unit site provide strong evidence that air quality has improved since the PSD baseline year. The magnitude of PSD baseline concentrations needed for current air quality to be in excess of allowable ambient increments is equal to or less than the MDL of instrumentation available at the time. Given that detectable concentrations have been consistently measured at both TRNP Units since 1980, the probability that baseline air quality was always less than MDL levels is remote. Therefore, exceedances of allowable increment consumption are presently not likely to be occurring in either TRNP Unit.